RHIC Program
Overview and Future Vision

Presented to
DOE-NP RHIC Program Review

by
Thomas B.W. Kirk
Associate Laboratory Director
HENP

Upton, NY
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Office of Science
U.S. DEPARTMENT OF ENERGY

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Plan of the Overview Talk

- Charge to the Reviewers from DOE Nuclear Physics
- RHIC Physics Program at BNL - current program
- Organization of BNL for the RHIC Program
- Contact Mechanisms with RHIC Users
- Future Directions of the RHIC Program
- ALD Priorities for the RHIC Program
- ALD Conclusions and Summary

Charge to the RHIC Program Reviewers

"…each panel member will be asked to evaluate and comment on:

- The quality, productivity, and significance of the research program conducted with the RHIC facility, particularly the heavy-ion and polarized proton activities, but also other non-Nuclear Physics sponsored activities, and the merit, feasibility and impact of the planned future program of the facility. [**Kirk, Zajc, Hallman, Busza, Beavis, McLerran, Bland, Aronson**]
- The effectiveness and appropriateness of accelerator operations including: an assessment of any technical or other potential roadblocks to achieving program objectives and approaches for overcoming them; the planned improvements and potential payoffs in support of the scientific program; and the technical support and services provided to the RHIC users. [**Lowenstein, Pile, Throwe, Roser, Harrison, Radeka**]
- The quality and appropriateness of Brookhaven Laboratory's interactions with, and nurturing of, its scientific user community. [**White-DePace, Greene, Kirk**]
- The merit and effectiveness of activities of Brookhaven Laboratory's accelerator and detector R&D activities, including its plans for upgrading the RHIC facility. [**Kirk, Roser, Ludlam**]
- The competence, creativity, and productivity of the Brookhaven laboratory scientific and technical staff in carrying out the above activities. [**Committee judgement**]"

Dennis Kovar's letter to the Laboratory of June 13, 2003

Brookhaven National Laboratory
Nuclear Physics Program

Mission Statement:

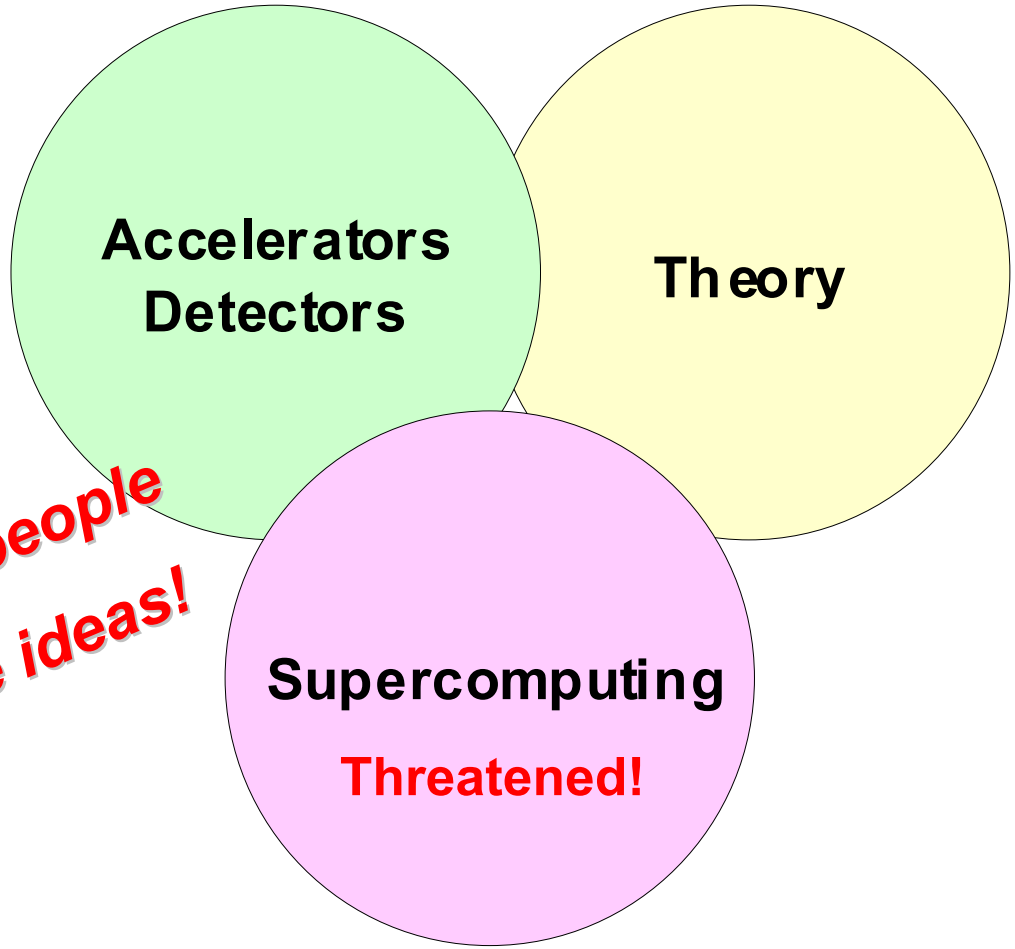
"Perform frontier research in theoretical and experimental nuclear physics; build, maintain and operate state of the art user facilities for nuclear physics; perform research and development work in accelerator science, experimental detector design and computing for NP; operate the National Nuclear Data Center and carry out construction projects in the NP area as assigned."

In support of this mission, the Laboratory operates large user facilities (AGS and RHIC) and carries on an in-house program of research in theoretical and experimental nuclear physics. Support of RHIC computing is provided by the RHIC Computing Facility at BNL. The National Nuclear Data Center is based at BNL. The work of the NP Program is also supported through the expertise of BNL's Instrumentation Division, a Lab-wide development organization reporting to the ALD-HENP.

Direction of the NP Program:

The Associate Laboratory Director of High Energy and Nuclear Physics directs this program. The work of the NP program is carried out in the Physics, Chemistry, ES&T and Collider-Accelerator Departments and in the Superconducting Magnet and Instrumentation Divisions.

Elements of a Productive NP Program



Plus talented people with creative ideas!

BNL embodies All three elements

Elements of the BNL NP Program

- **Operation and upgrade of forefront user facilities for NP experiments**
  - *RHIC facility (a unique collider facility for heavy-ion and polarized proton beams)*
  - AGS Complex (highest intensity proton synchrotron in the world, off in FY03)

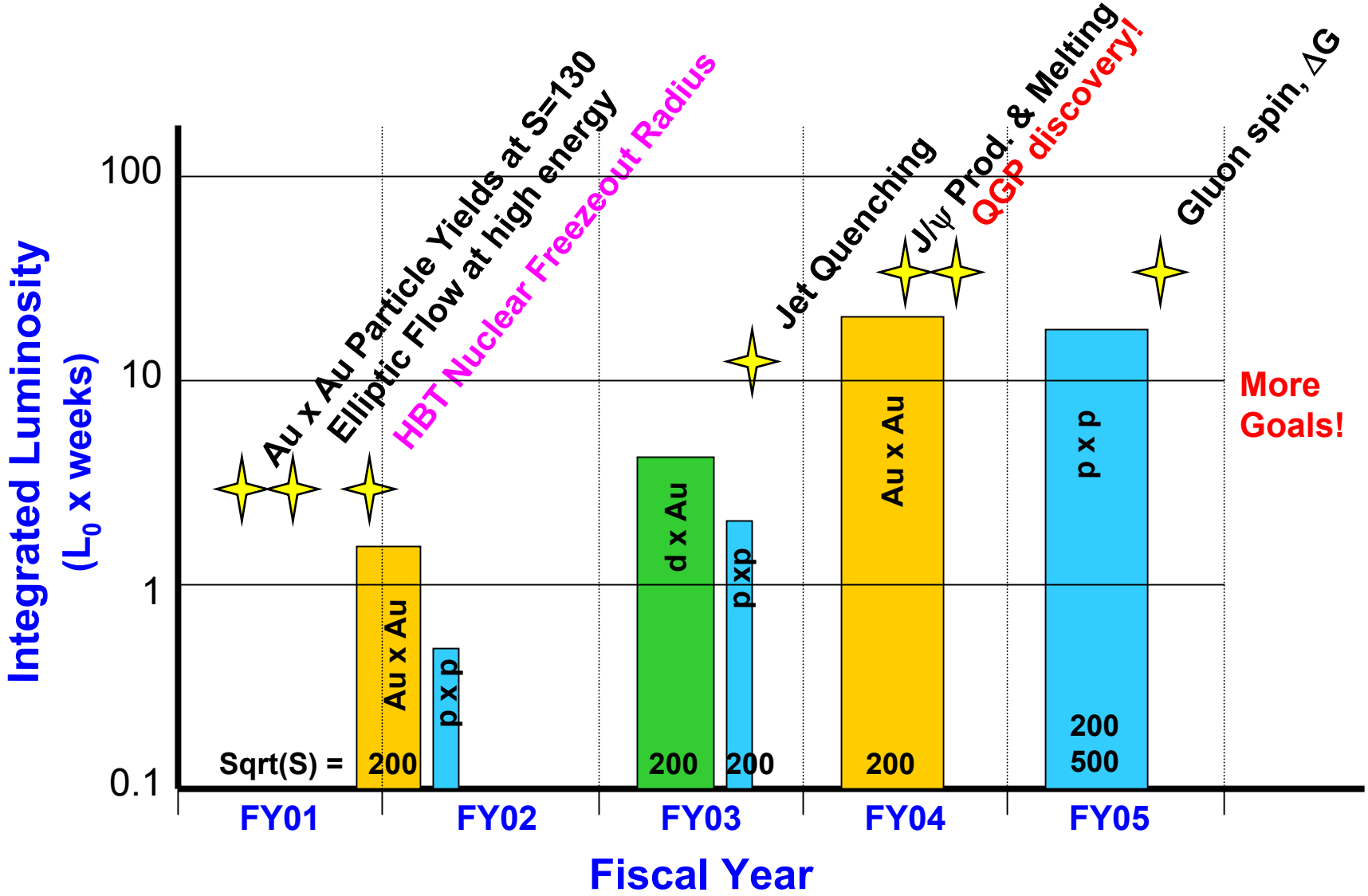
- **Performance of a world class, in-house program of basic research in theoretical and experimental nuclear physics**
  - *five experimental groups of key value to forefront efforts at RHIC*
  - *a theoretical group of broad capability with productive links to particle physics*
  - *close collaboration with the RIKEN BNL Research Center to enhance research*
  - productive collaboration in the SNO neutrino experiment
  - maintenance and improvement of the National Nuclear Data Center at BNL

- **Performance of a leading R&D effort in the development of advanced accel. & detector concepts and computing support for NP research**
  - *continued improvement of the RHIC-AGS complex using AIP and other funding*
  - *development (with Instrumentation Division) of novel particle detectors*
  - *operation & development of the RCF for support of RHIC computing*

Program elements addressed in this review shown in *red italics*


PHOBOS
10:00 o'clock
12:00 o'clock
BRAHMS & PP2PP (p)
2:00 o'clock
RHIC
4:00 o'clock
PHENIX (p)
8:00 o'clock
STAR (p)
6:00 o'clock
NASA - BAF
μ g-2
HEP/NP (p)
LINAC
BOOSTER
AGS
TANDEMS

Past & Future RHIC Physics Milestones



1 RHIC Wk = 3.0 x 10^5 secs

T. Kirk
July 9, 2003

L_0 = 2.0 10^{26} cm^{-2} sec^{-1}, AuAu @ 200

L_0 = 5.0 10^{30} cm^{-2} sec^{-1}, p↑p↑ @ 200

Current RHIC-related Research Programs

- **RHIC Experiments using Au(d) x Au and polarized proton collisions**
  - BRAHMS Exp. (2-arm spectrometer with tracking & particle ID)
  - PHOBOS Exp. (all Si detector with 4π acceptance, TOF and magnetic tracking)
  - STAR Exp. (large TPC in 0.5T B-field; EM calorimetry + partial TOF/particle ID)
  - PHENIX Exp. (large, multi-function magnetic detector with extensive particle ID)
  - pp2pp elastic scattering experiment with polarized protons (ended FY03)
  - integration of RHIC spin physics with RIKEN BNL Research Center physicists

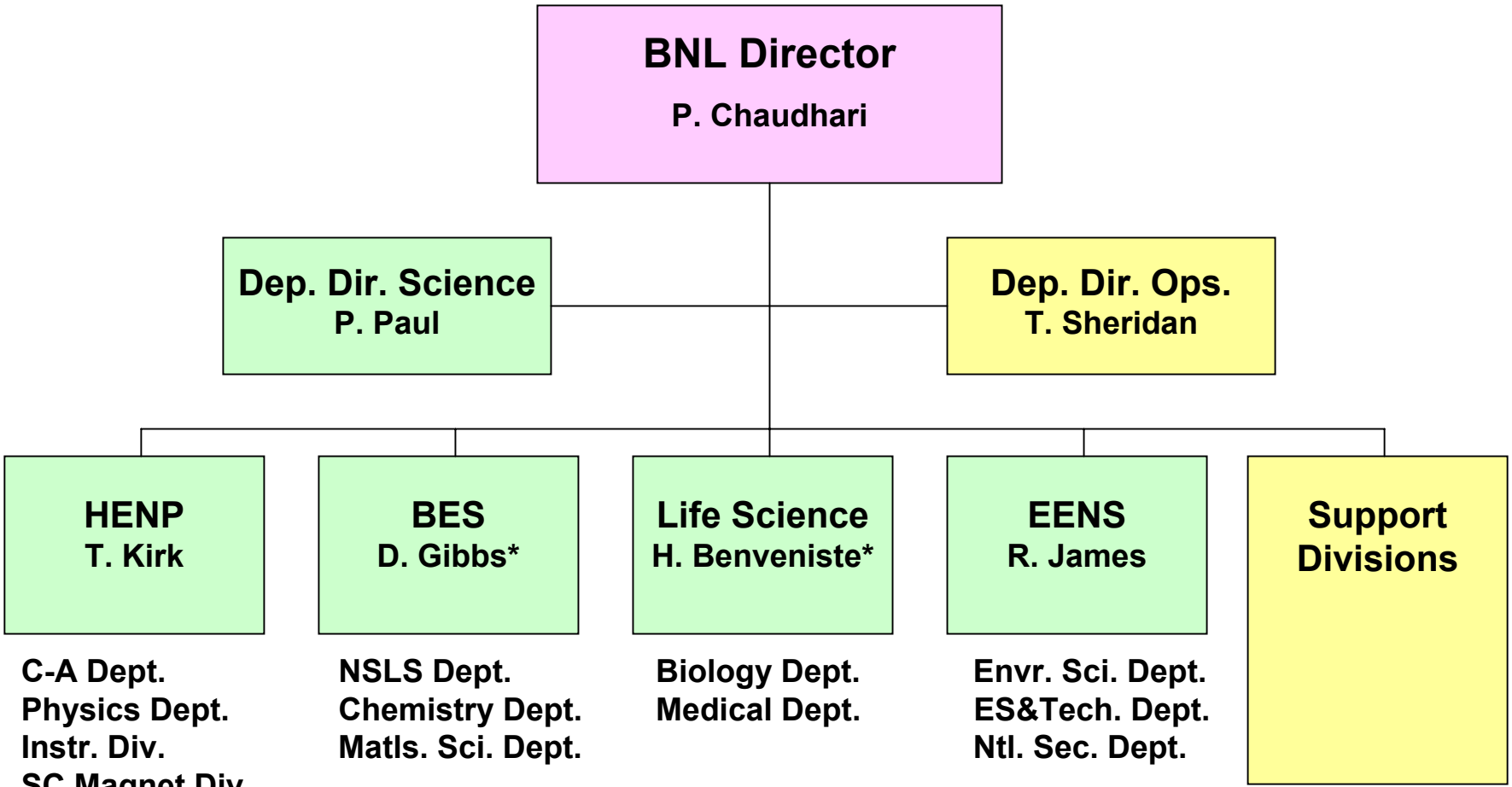
- **Theoretical Nuclear Physics**
  - a growing and active nuclear theory group emphasizing HI and spin physics
  - close collaboration of BNL NP theorists with the RBRC at BNL
  - sponsor/partner in many workshops and topical conferences on theory subjects

- **Accelerator and Detector R&D Program**
  - continuing upgrades and improvement studies in the RHIC-AGS complex
  - detector systems R&D in the Laboratory and in collaborating universities
  - continuing detector R&D in BNL's renowned Instrumentation Division

RHIC in the Brookhaven Laboratory Context

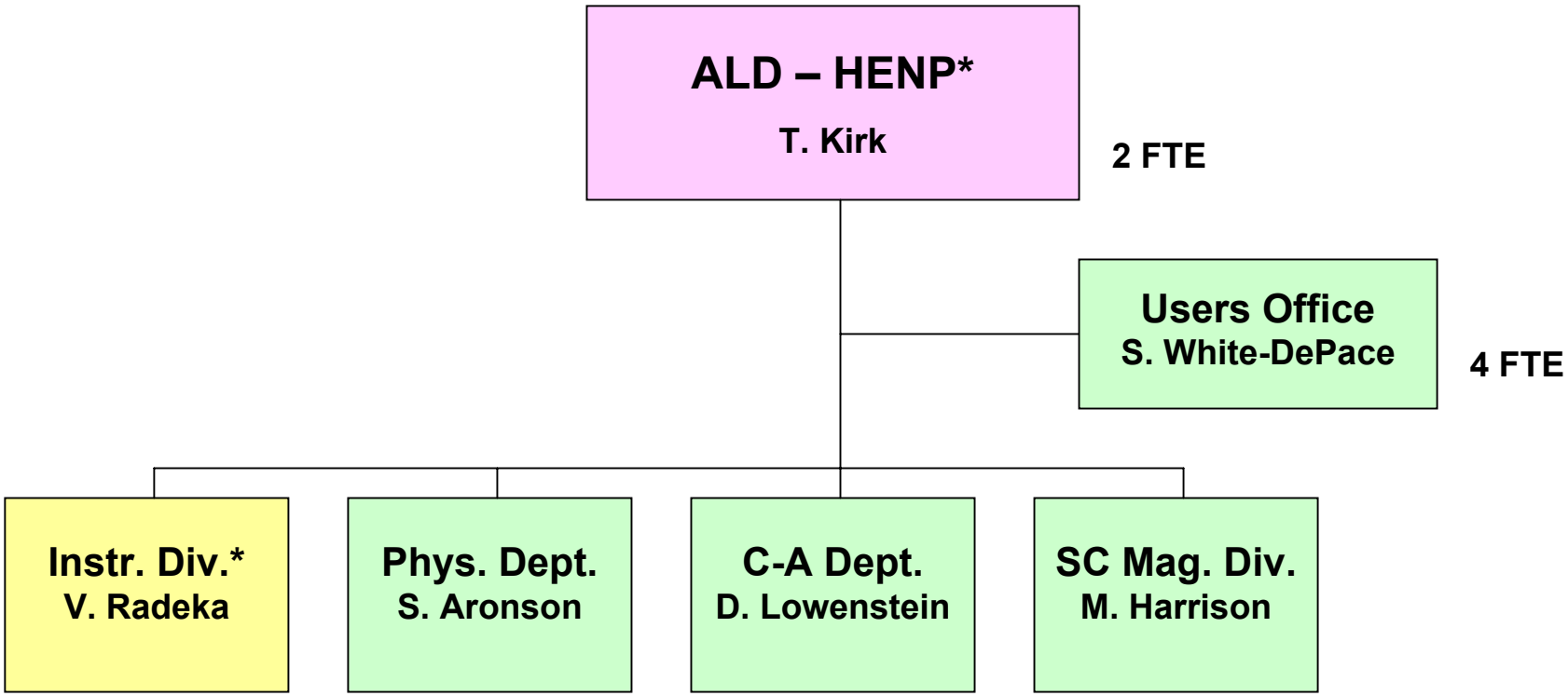
- **The RHIC-AGS Accelerator Complex at BNL**
  - RHIC-AGS is the *flagship DOE user facility* at BNL
  - RHIC is the *top HI facility in the world* until at least 2008 (LHC at CERN)
  - AGS remains the *highest intensity proton synchrotron* in the world
- **RHIC and AGS Experiments at BNL**
  - the 4 RHIC collider detectors *cover the gamut of first-generation RHIC physics*
  - these detectors are *well-suited to spin physics* with polarized proton beams
  - RHIC serves a current total of over 1000 NP users from all over the world
  - ideas for future RHIC and AGS experiments have been received by BNL
- **RHIC-Related Nuclear Physics Research**
  - 5 experimental and 1 theoretical RHIC-related physics research groups at BNL
  - Riken BNL Research Center contributes strongly to theory and spin physics
  - SciDAC R&D grant for *QCDOC supercomputer* for *BNL Lattice Gauge Center*
- **BNL's Instrumentation Division**
  - Nuclear Physics is a *prime beneficiary of BNL's Instrumentation Div.*
  - RHIC-related technologies are being adopted for use in other BNL programs

BNL Science Organization



* Interim ALD

BNL - HENP Organization Chart



* G&A supported organization

BNL HENP Program Advisory Committee

Stanley Brodsky	Stanford Linear Accelerator Center
Sarah Dawson	Brookhaven National Laboratory
Gerald T. Garvey	Los Alamos National Laboratory
Donald Geesaman	Argonne National Laboratory
Miklos Gyulassy	Columbia University
Wick Haxton	University of Washington
Robert Jaffe	Massachusetts Institute of Technology
Berndt Mueller	Duke University
Jack Sandweiss, Chairman	Yale University

RHIC Communications

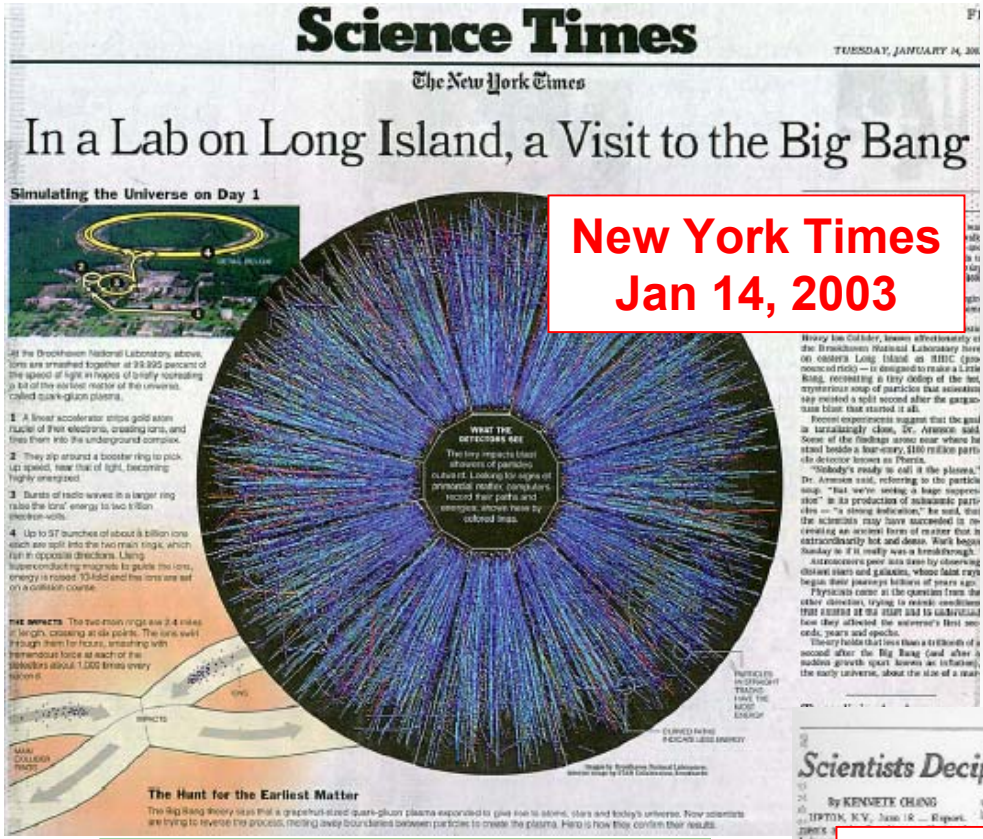
In the Charge for this review, the issue of BNL communication with RHIC users is noted. Here, we list the current communications modes in use:

- **The web is the main venue for communication of facility/user information**
  - http://www.bnl.gov/rhic
  - http://www.bnl.gov/userscenter
  - http://agsrhichome.bnl.gov
  - http://www.bnl.gov/henp
- **RHIC experiments maintain up to date publ/preprint lists on their web pages**
- **Time meetings and user status meetings are held weekly during RHIC runs**
  - running experiments representatives attend and participate in decision-making
  - C-AD staff leaders and managers report day to day status and actions
- **BNL organizes physics and evolution workshops for new RHIC directions**
- **RHIC-AGS Users Group and Exec. Comm. interact with BNL management**
- **The long term RHIC program responds to user proposals and PAC advice**
- **The ALD-HENP meets monthly with RHIC Spokespersons on current issues**
- **RHIC-AGS Users Office and BNL Quality of Life Committee respond to needs**

Recent NP Program Highlights

- **2002 Nobel Prize to Ray Davis**
- **RHIC d-Au run in RHIC clarified the nature of jet quenching in Au-Au data**
- **First data using longitudinally polarized proton beams in RHIC**
- **RHIC Physics active - June 18 Special Colloquium on *Jet Quenching***
  - reports from 4 RHIC experiments with important evidence for QGP
  - speeches by J. Marburger, P. Rosen and D. Kovar
  - AP story in 153 papers & TV stations plus Science, NYT and Newsday
- **Lattice Gauge Center at BNL; SciDAC Phase-I grant for *QCDOC software***
- **Gerry Bunce and Craig Woody named APS Fellows**
- **BNL's future program addresses 6 of the 11 key questions noted in the 'Quarks to the Cosmos' planning document - a promising future vision...**

RHIC makes news, and physics….



Science Times

The New York Times

TUESDAY, JANUARY 14, 2003

In a Lab on Long Island, a Visit to the Big Bang

Simulating the Universe on Day 1

WHAT THE DETECTORS SEE

The Hunt for the Earliest Matter

New York Times
Jan 14, 2003

No Small Matter

Call it "Atomic Theory for Dummies." For non-scientific types, here's a primer on the little protons, quarks and gluons that have generated so much excitement at Brookhaven lab.

Section of the Relativistic Heavy Ion Collider used in the Brookhaven experiments.

Quark

A building block of protons and neutrons (and, thus, of matter). Quarks are bound together by a powerful force carried by gluons.

Atom

A building block of matter, which is defined as anything that has mass. A million times smaller than the thickness of a human hair, an atom is made up of electrons and a nucleus. The nucleus, which accounts for most of an atom's mass, is composed of protons and neutrons.

Newsday
June 19, 2003

A Matter of Accomplishment

Primordial soup's on, in an LI lab

By Earl Lane

Washington — By a process of elimination, researchers at Brookhaven National Laboratory say they are tantalizingly close to showing that a huge ion collider at the lab has produced a novel form of matter unseen since the dawn of the universe.

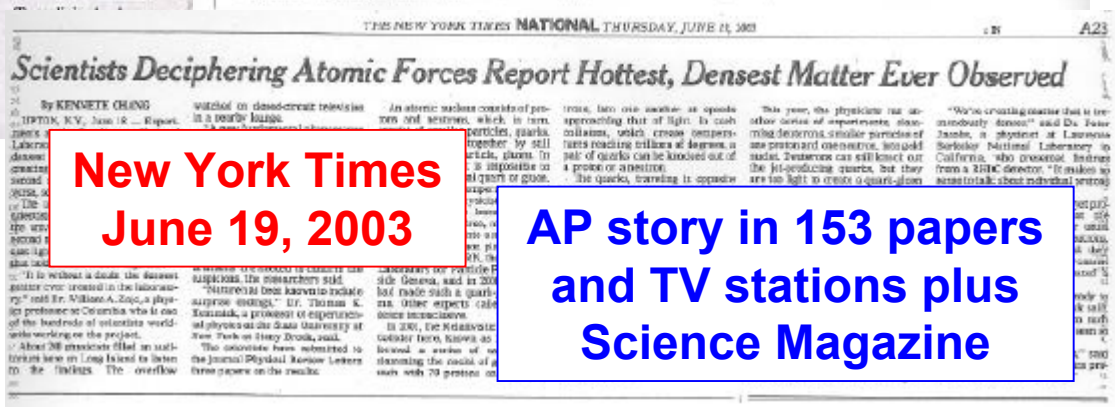
The latest results from experiments at the lab's Relativistic Heavy Ion Collider will be presented at a colloquium today at Brookhaven. Physicists built the device, located in a tunnel 2.4 miles around, in hopes of creating a hot primordial soup, called the quark-gluon plasma, that existed a few millionths of a second after the birth of the universe.

One theorist, Hikka Gyulassy of Columbia University, said he is convinced the soup already has been produced in the Brookhaven machine. If so, it would be one of the first great triumphs of 21st century physics. But the teams doing the experiments are not ready to make a claim yet.

William Zajc, a spokesman for PHENIX, one of the large collaborations of experimentalists at the collider, said there is little question "the matter we're producing is qualitatively different than what's been seen at any other accelerator." But he said, "Even were such was the quark-gluon plasma, we would have additional tests."

Still, the new data have created a buzz at Brookhaven and beyond. "The indicators they are seeing in the experiments are very exciting," said John H. Marburger III, the White House science

See MATTER on A32



THE NEW YORK TIMES NATIONAL THURSDAY, JUNE 19, 2003 A23

Scientists Deciphering Atomic Forces Report Hottest, Densest Matter Ever Observed

By KENNETH CHANG

New York Times
June 19, 2003

AP story in 153 papers
and TV stations plus
Science Magazine

BRAHMS: 3 Phys. Rev. Lett.;
PHOBOS: 9 Phys. Rev. Lett.
PHENIX: 20 Phys. Rev. Lett.
STAR: 18 Phys. Rev. Lett.

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RHIC Future Directions

- **Quarks to the Cosmos – the Big Questions**
- **RHIC Facility Evolution (RHIC physics directions in Experiments talks)**
- **RHIC Facility planning assumptions**
- **Near Term RHIC Facility Evolution**
- **BNL large facilities possible construction schedules**
  - RSVP
  - RHIC II luminosity upgrade, accelerator & detectors
  - Very Long Baseline Neutrino Oscillations
  - eRHIC facility, electron ring and new detector
- **ALD Priorities for the RHIC Program**

"Connecting Quarks with the Cosmos"*

(*BNL HENP Vision for Future Facilities Development*)

1. **What is Dark Matter? – *ATLAS Experiment***
2. **What is the nature of the Dark Energy? – *LSST Collaboration?***
3. How did the Universe Begin?
4. Did Einstein have the Last Word on Gravity?
5. **What are the masses of the neutrinos and how have they shaped the Evolution of the Universe? – *MINOS; VLB Neutrino Experiment & Super Beam***
6. How do Cosmic Accelerators work and what are they accelerating?
7. **Are Protons Unstable? – *UNO Experiment Collaboration***
8. **What are the New States of Matter at exceedingly High Density and Temperature? – *RHIC, RHICII and eRHIC Collider and Experiments***
9. **Are there additional Space-Time Dimensions? – *ATLAS Experiment***
10. How were the elements from Iron to Uranium made?
11. Is a new theory of Matter and Light needed at the Highest Energies?

* "Connecting Quarks with the Cosmos", National Research Council of the National Academies, 2003

RHIC Future Vision - Facility Evolution

- **RHIC will be unchallenged until LHC begins research in FY08**
  - there are no other Heavy Ion facilities in the world in the QGP energy regime
  - the RHIC Polarized Proton capability is unique for frontier spin physics
- **Continuing yearly upgrades will keep RHIC at the research frontier**
  - AIP funding is expected to provide continuing accelerator improvements
  - Facil. Cap. Eqp. Funds will enable continuous improvement of RHIC & RCF
  - Facil. Cap. Eqp. Funding will enable detector improvements to continue
- **Conclusions from the NSAC '2001 Long Range Plan' exercise**
  - **'RHIC II'** luminosity upgrade will provide important scientific value
  - collider luminosity upgrades of up to a factor 40 can be foreseen
  - RHIC experiments have already identified clear luminosity upgrade paths
  - **R&D funding** is *essential for success* of the long term RHIC Program
  - DOE and BNL are mutually planning this scientific growth path for RHIC
- **The long-term evolution of RHIC evaluated during NSAC Study**
  - **'eRHIC'** rated 'central to progress in the field' - Orbach Future Facilities Study
- **SC Magnet Div is a key unit for developing future RHIC technologies**
  - e-cooling and eRHIC superconducting RF and magnet systems

Planning Assumptions for RHIC Evolution

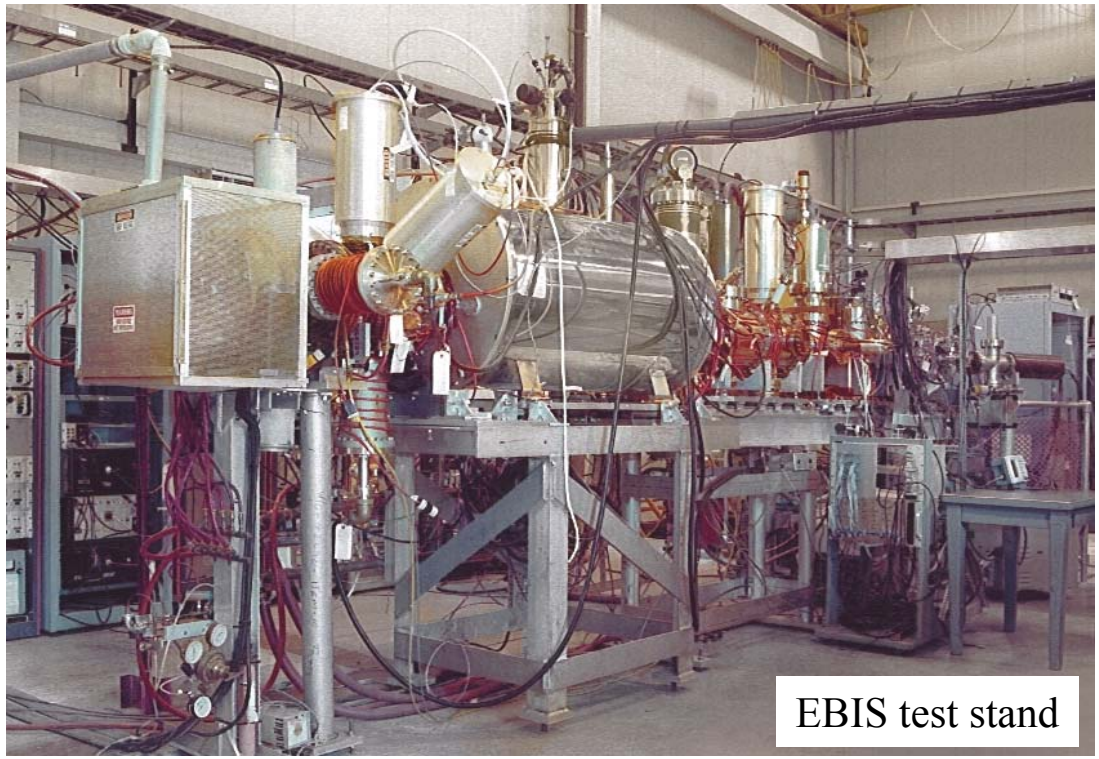
(assumes 'reasonable' NP budgets)

- **RHIC HI Luminosity will grow continuously in time**
  - FY01-03, Au-Au, d-Au beams established; FY04-05 reach design luminosity
- **RHIC pp Luminosity improvements in future years**
  - FY02-04, $p\uparrow p\uparrow$, beam tests $\rightarrow$ 5×10^{30} cm $^{-2}$ sec $^{-1}$ @ $(S)^{1/2}$ = 200 GeV
  - FY05, $p\uparrow p\uparrow$ run at 5×10^{30} [10×10^{30}] cm $^{-2}$ sec $^{-1}$ @ $(S)^{1/2}$ = 200 [500] GeV
- **Existing Detectors will be improved continuously**
  - BRAHMS & PHOBOS reached their full Phase I configuration in FY01
  - STAR & PHENIX completed Phase I construction during the FY02 shutdown
  - all detectors at Phase I baseline for the FY03 run [except STAR EM Cal]
- **Potential new detectors in RHIC will be driven by physics needs**
  - RHIC I physics is underway at this point and the exciting physics results are emerging (***jet quenching, flow***); some believe ***QGP*** has been seen
  - new detectors could be required for unanticipated physics developments
- **LHC HI will compete for *energy reach*, not integrated Luminosity**
  - LHC heavy ion will not run before 2008; LHC HIs will run only 4 wks/yr

Planning Steps

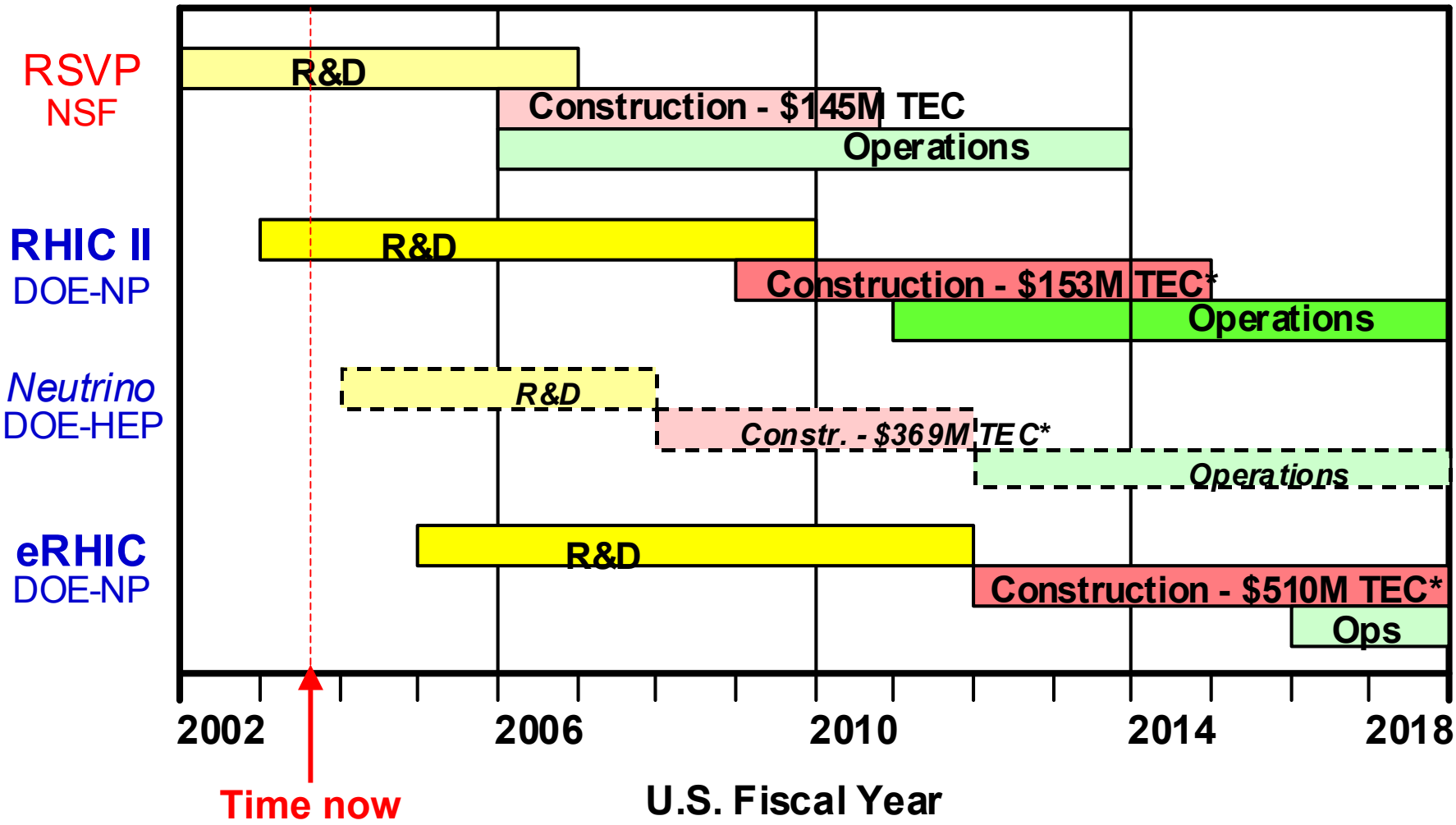
- **Vision for RHIC Physics**
  - NSAC Long Range Plan and supporting topical workshops set the agenda
  - 'Quarks to the Cosmos' – 11 deep questions for the new decade gave input
  - Ray Orbach's Future Facilities Workshops – key physics directions for DOE-OS
- **RHIC Physics Plans and Program Evolution at BNL**
  - RHIC Experiments 'strategic physics goals' white papers due July 31, 2003
  - discussion with PAC of the strategic goals papers
  - the strategic goals papers are intended to cover the decade leading up to RHIC II initiation
  - appropriate workshops and planning forums will be carried out in time to refine the future planning on the decadal and the 20-year time scales
- **RHIC Program Planning with DOE Nuclear Physics**
  - following the PAC Meeting, BNL will meet with DOE to define planning assumptions for the decadal and the 20-year time scales
  - after DOE concurrence has been achieved, the key milestones will be developed – CD0, CD1, etc. by DOE and BNL together with supporting papers and documents

Near-Term Project - EBIS/Linac RHIC Pre-Injector



- Highly successful development of Electron Beam Ion Source (EBIS) at BNL
- EBIS allows for a reliable, low maintenance Linac-based pre-injector replacing the Tandem Van de Graaffs
- Produces beams of all ion species including Uranium and polarized He3 (for eRHIC)
- Ready to start construction; Cost: approx. 16-18 M$; Schedule: 2005/6 – 2008/9

BNL HENP Accelerator Facility Initiatives



* These estimates in FY03 dollars and do not include escalation.

ALD Priorities for the RHIC Program
(in decreasing order)

- **RHIC must run for colliding beam data every year**
  - the goal is 37 weeks/yr, of which at least 30 are for experiments
  - HI/p↑ mix will be driven by Beam Use Proposals & PAC recommendations
  - a nominal beam mix, averaged over time, will be 2/3 HI, 1/3 p↑p↑
- **RHIC research requires strengthening of funding support**
  - BNL and collaborating universities are both critically under-funded
- **RHIC will require continuous upgrade/capital improvements**
  - AIP funding requires a funding level of $5M/yr or greater
  - facility capital funding for accelerator maintenance requires $1M/yr
  - special projects requiring more will result in competitive proposals to DOE
- **Existing Detectors will require continuous upgrade/cap actions**
  - the facilities capital equipment level needed for RHIC detectors is ~$5M/yr
  - computing support in RCF will require $2M/yr to meet data processing needs
  -competitive research capital equipment funds of ~$5Myr likely to be proposed
- **Other AGS/RHIC experiments will be accommodated as possible**
  - a RHIC 8-hour store allows up to 20hrs/day for AGS fixed-target physics

Priorities are applied in the most program-effective manner, not in simple series order.

ALD Conclusions and Summary

- **RHIC has been scientifically productive**
  - data from the d-Au run of FY03 Has already made a big physics splash
  - first **longitudinal polarized proton data** during the FY03 run
  - theoretical analysis and interpretation has been fully active and engaged
  - **41 refereed publications** to date (mostly **PRL**); 14 more papers submitted
- **RHIC and its experiments have reached their design levels**
  - all RHIC experiments have reached their full design configuration
  - RCF data-taking/archiving/analysis computing infrastructure performs well
- **Funding for the RHIC Facility has been short of optimum**
  - RHIC facility funding expected to reach 27 cryo/20 physics weeks in FY04
  - RHIC research funding levels for Labs and universities continues to be tight
  - **R&D** for future RHIC facility evolution was initiated (partial strength) in FY03
- **Viable & competitive future directions for RHIC have been identified**
  - the RHIC luminosity upgrade path is well-matched to developing HI physics
  - the **RHIC II** upgrade will contribute effectively to the later RHIC program
  - the **eRHIC** facility will provide unique new physics in the longer-term future